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# Carbon quantification of diverse landscapes using multi-spectral 3D digital aerial imagery: complex pine savanna in Belize as a case study

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# Acknowledgements


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# Pine savanna of Belize

# Pine savanna associations

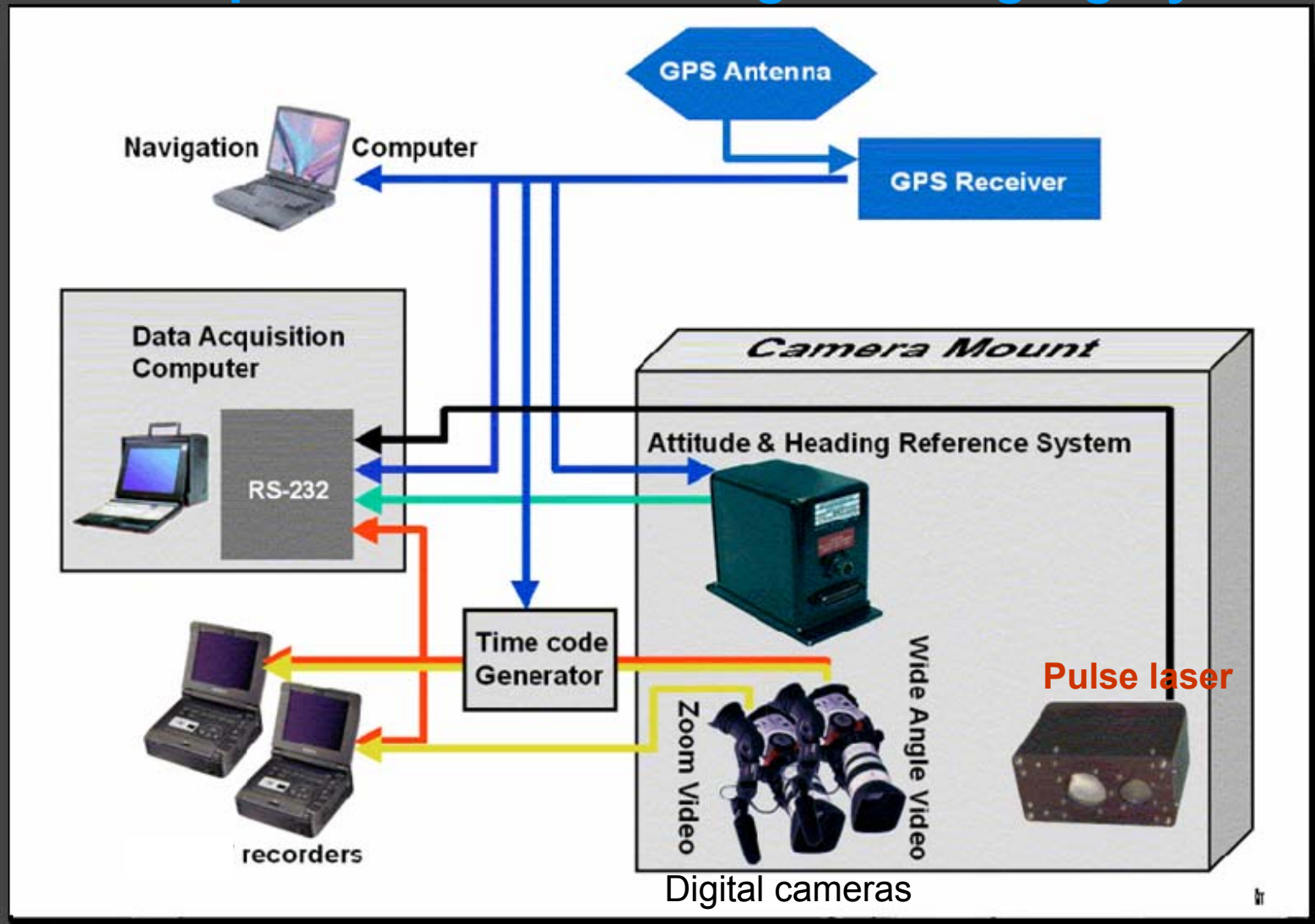
# How to measure the carbon stocks in this complex system

- Consists of many sub-types but difficult to stratify as they are widespread with no distinct boundaries
- Because very heterogeneous, would need many ground plots to sample for high precision
- Not only a large number of ground plots but also would require a lot of harvesting of plant material because system is characterized by pine and hardwood trees, woody shrubs, palmettos, grasses

# Goal of study:

- Determine if multi-spectral, 3D aerial digital imagery (M3DADI) system can decrease the need for extensive ground measurements while creating accurate and precise carbon estimates in a cost-effective manner
- Two steps:
  - Collect and analyze digital imagery
  - Collect and analyze ground data to use in combination with imagery

# Multispectral 3D aerial digital imaging system

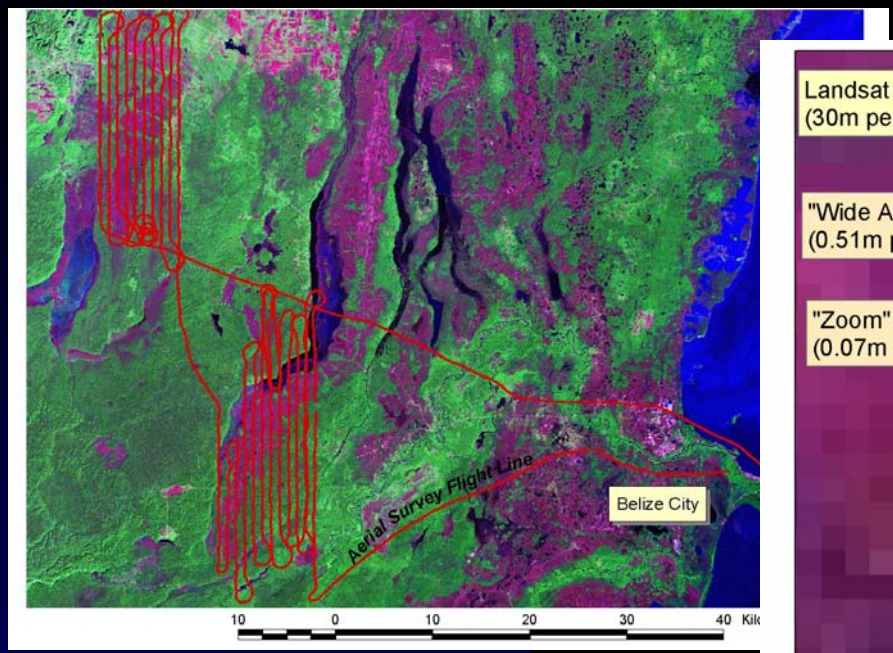


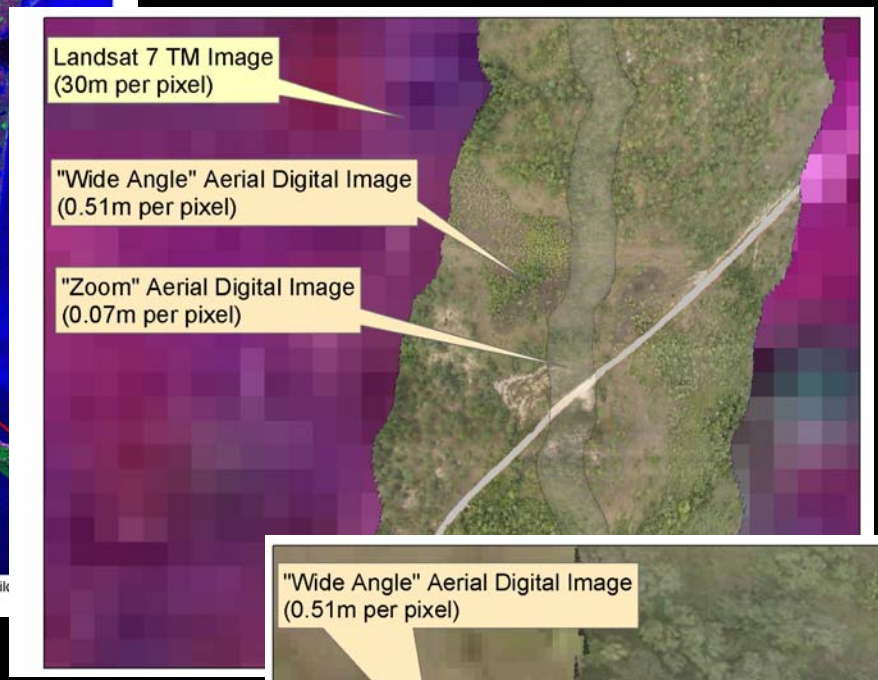

The digital imaging system includes a digital gyroscope and pulse laser along with dual digital cameras, fly transects and construct georeferenced mosaics that can be displayed in 3D

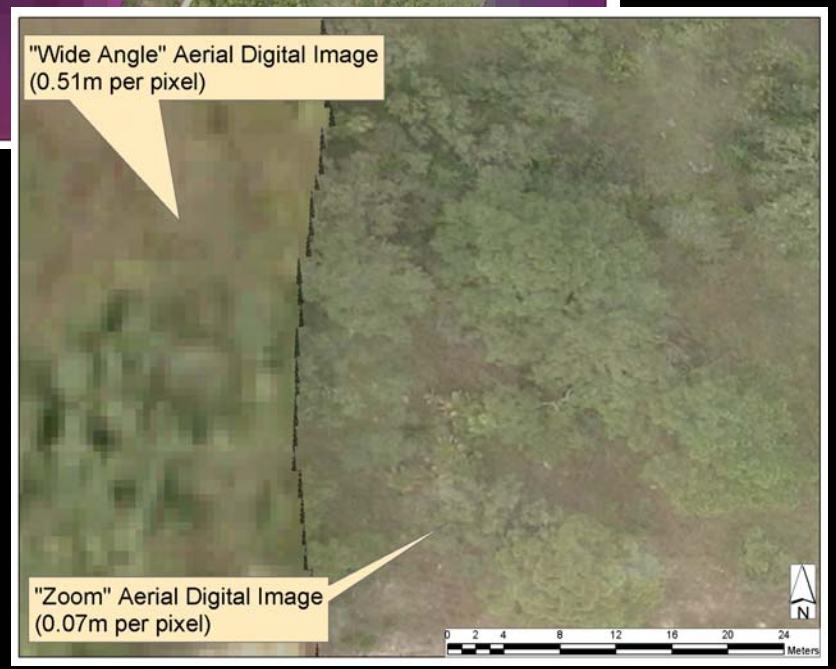
# Multispectral 3D Aerial Digital Imaging System

- Fits in a portable camera pod,
- Will fit into commercial airline luggage
- Attaches to any Cessna

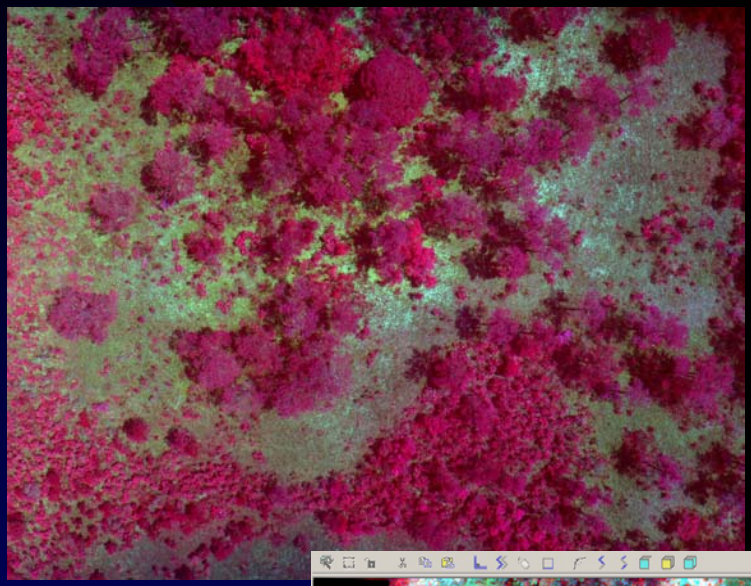
# Collection of digital imagery

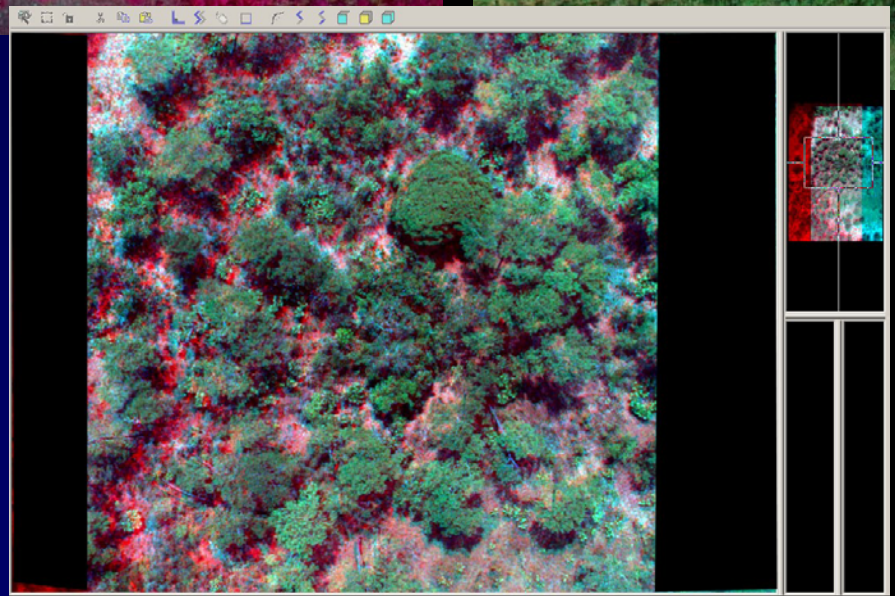


# Analysis of digital imagery





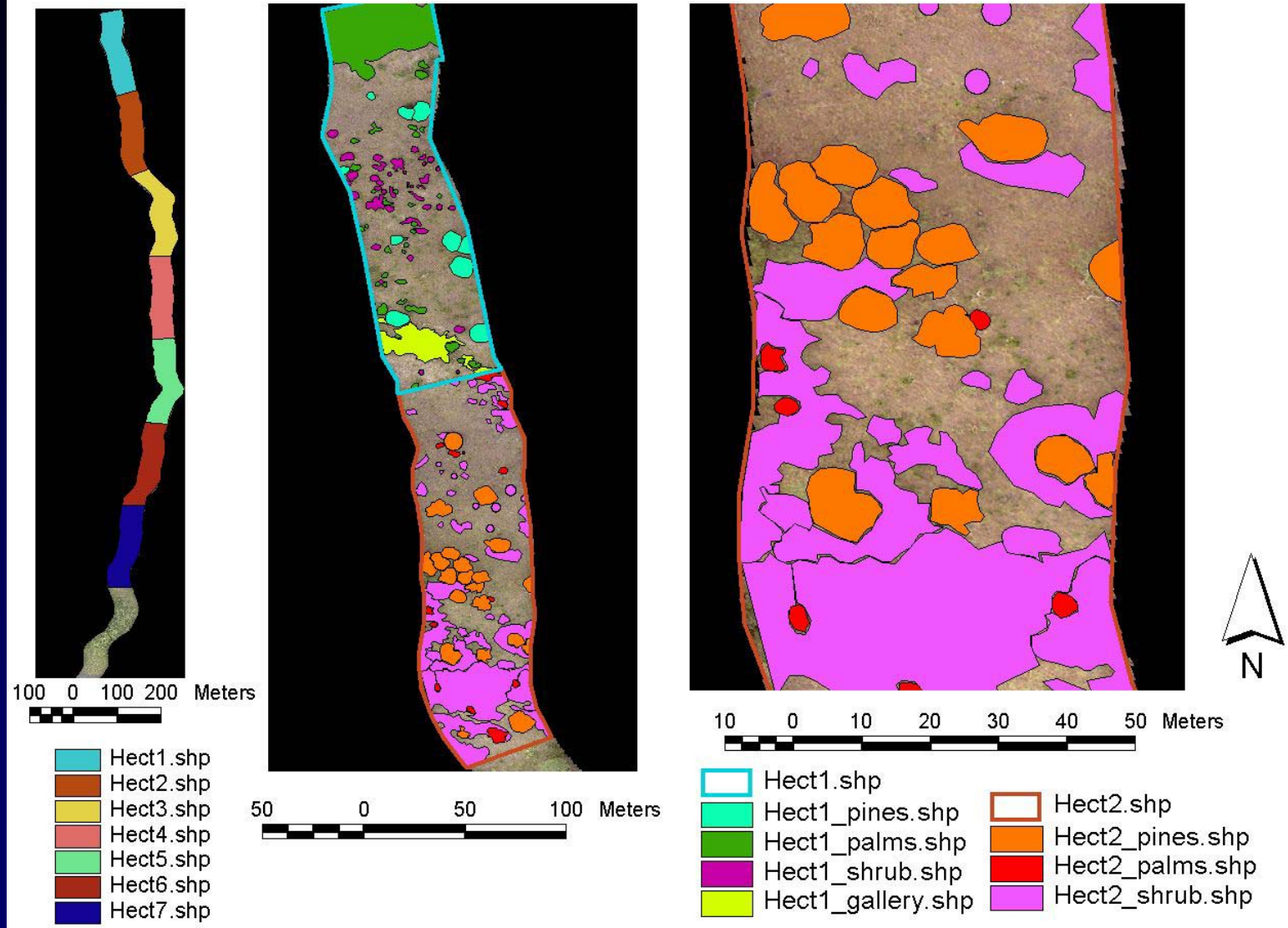
# Example of M3DADI data in 3D

This 3D approach provides methods for studying and mapping terrestrial systems

# Noel Kempff Mercado National Park, Bolivia

These models can be interacted with data from a laser to calibrate tree height, measured, and re-flown to monitored change in the forest on an individual tree level.

# Analyze ~1 ha plots on the imagery to obtain area of crowns or cover and tree heights



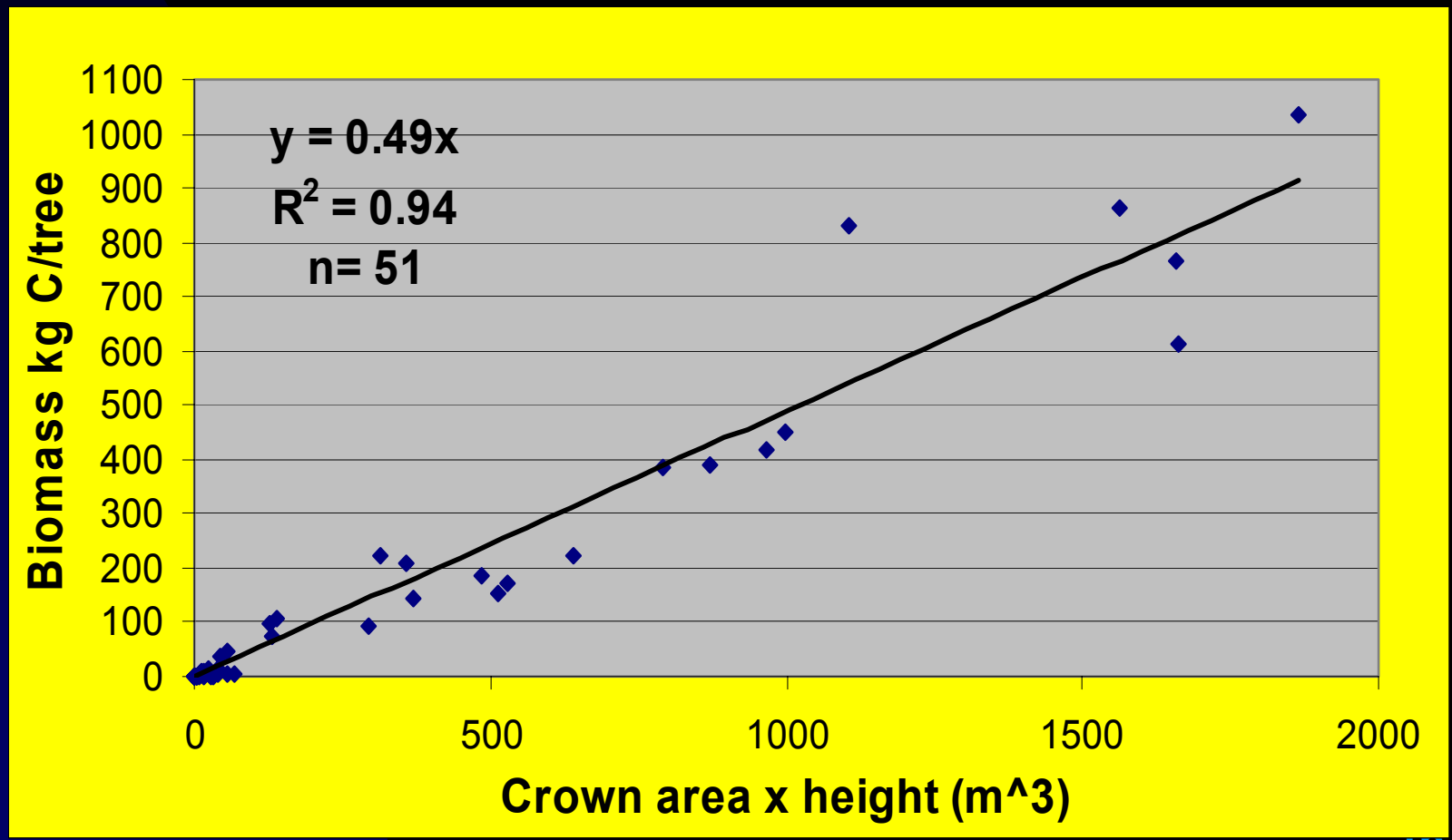
# Areas of each vegetation type per plot

| Plot number | Total plot | Grasses | Shrub | Pine | Palms |
|---|---|---|---|---|---|
| | Area (m^2) | | | | |
| 1 | 10,000 | 8,721 | 376 | 522 | 281 |
| 2 | 9,933 | 5,700 | 2,959 | 1,087 | 187 |
| 3 | 10,204 | 3,792 | 2,919 | 3,039 | 455 |
| …….. | …….. | …….. | …….. | …….. | …….. |
| 19 | 9,855 | 5,590 | 3,256 | 908 | 101 |
| 20 | 9,777 | 5,321 | 3,406 | 1,008 | 42 |
| **Total ($m^2$)** | **192,424** | **98,765** | **62,836** | **23,967** | **9,378** |

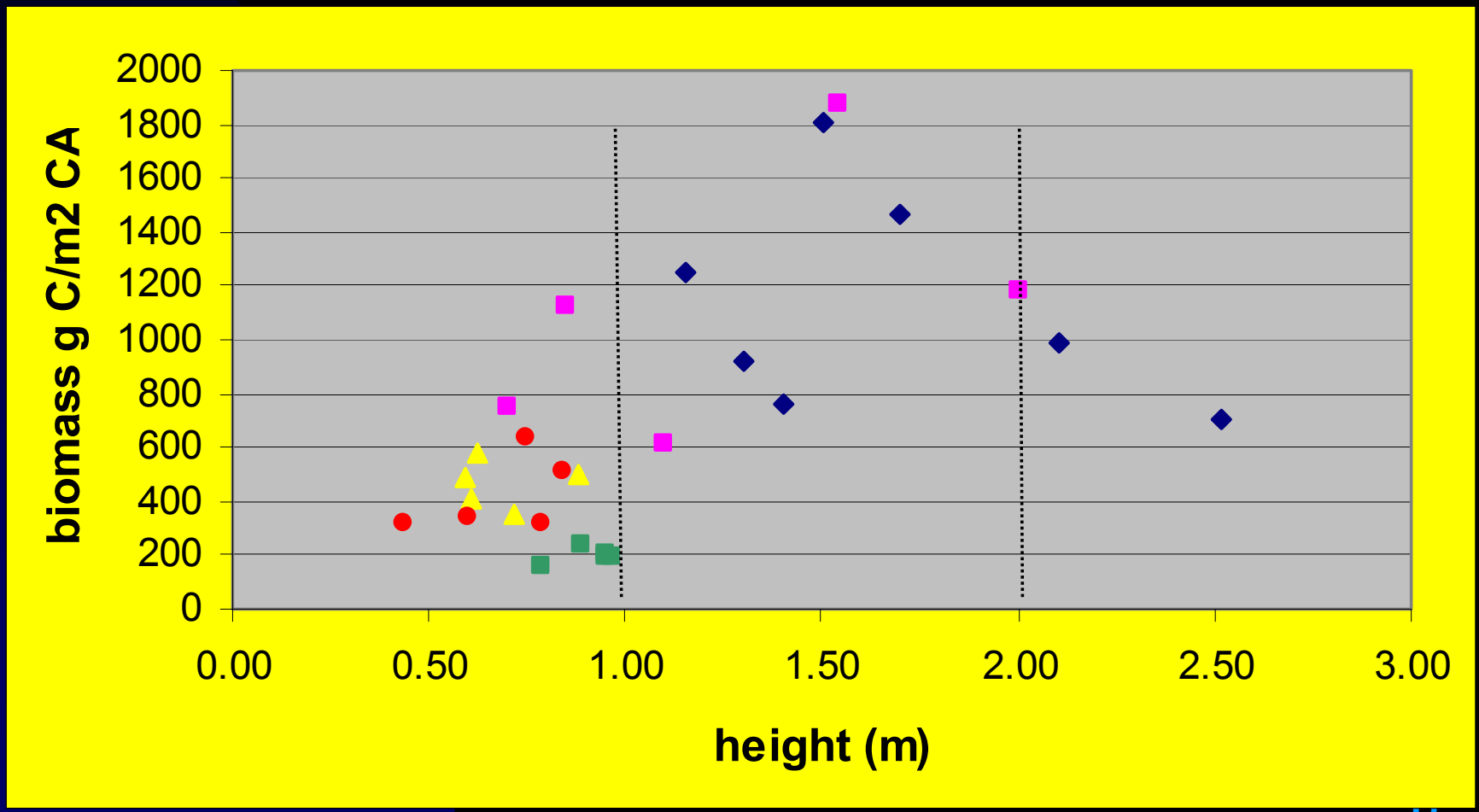
# Field data analysis

- From imagery can measure:
  - crown area and height of trees
  - area of canopy cover of shrubs and palmetto and height classes
- From destructive harvest methods develop robust relationships between measurable indices from the imagery and biomass carbon for all plant types

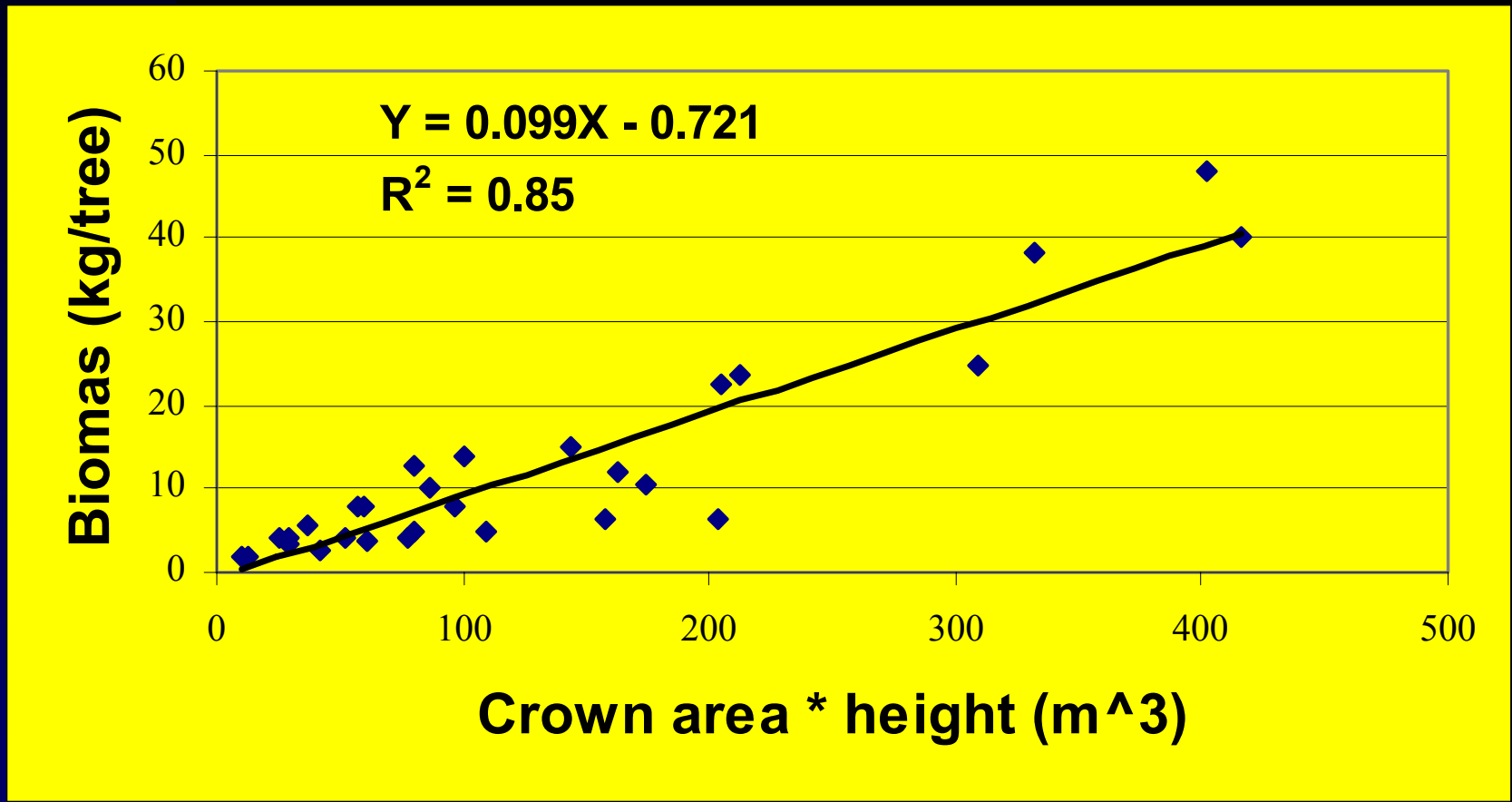
# Pine trees: relationship between biomass per tree and crown area x height



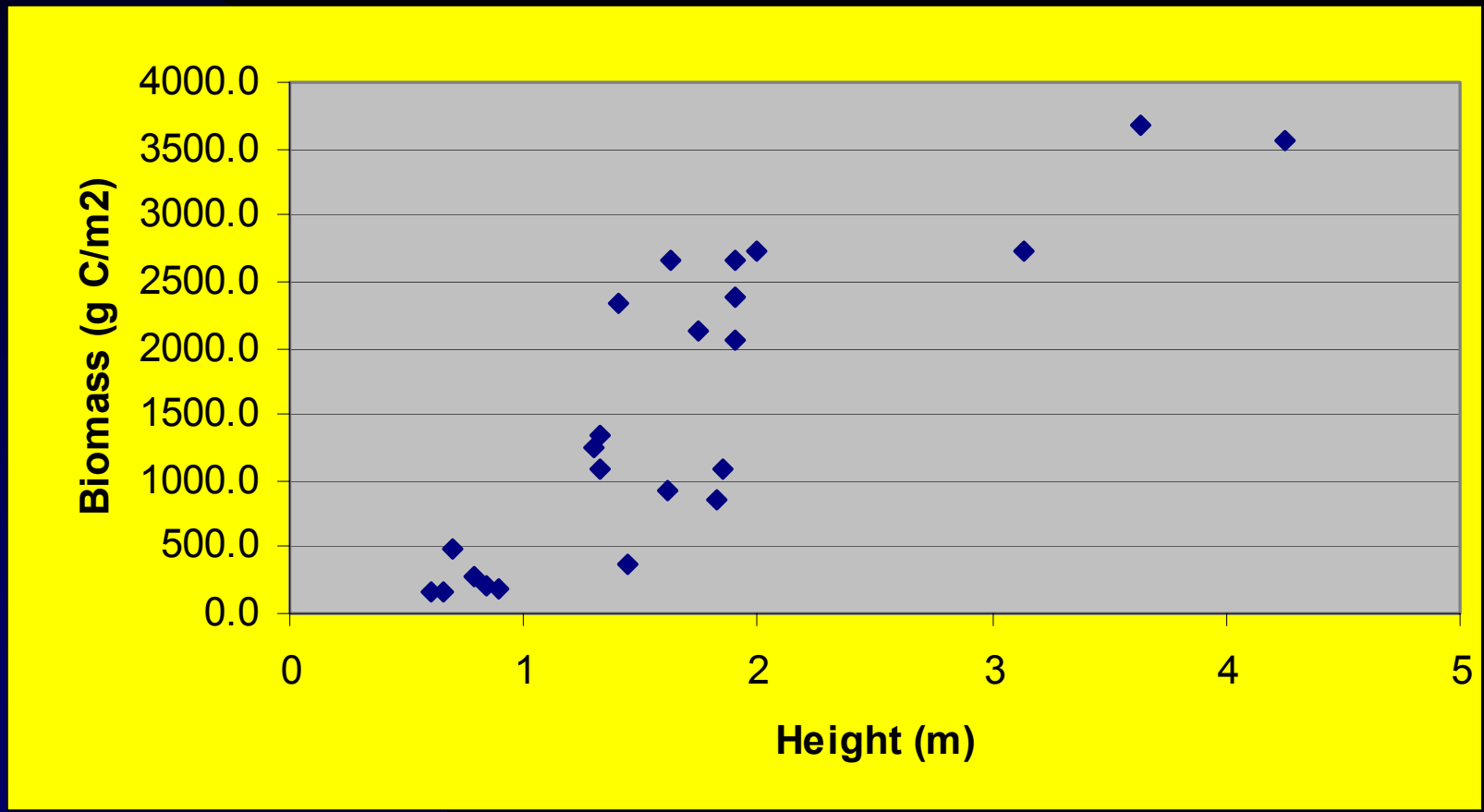
# Shrubs: biomass per unit of crown area versus height



# Calabash trees: biomass and crown area x height



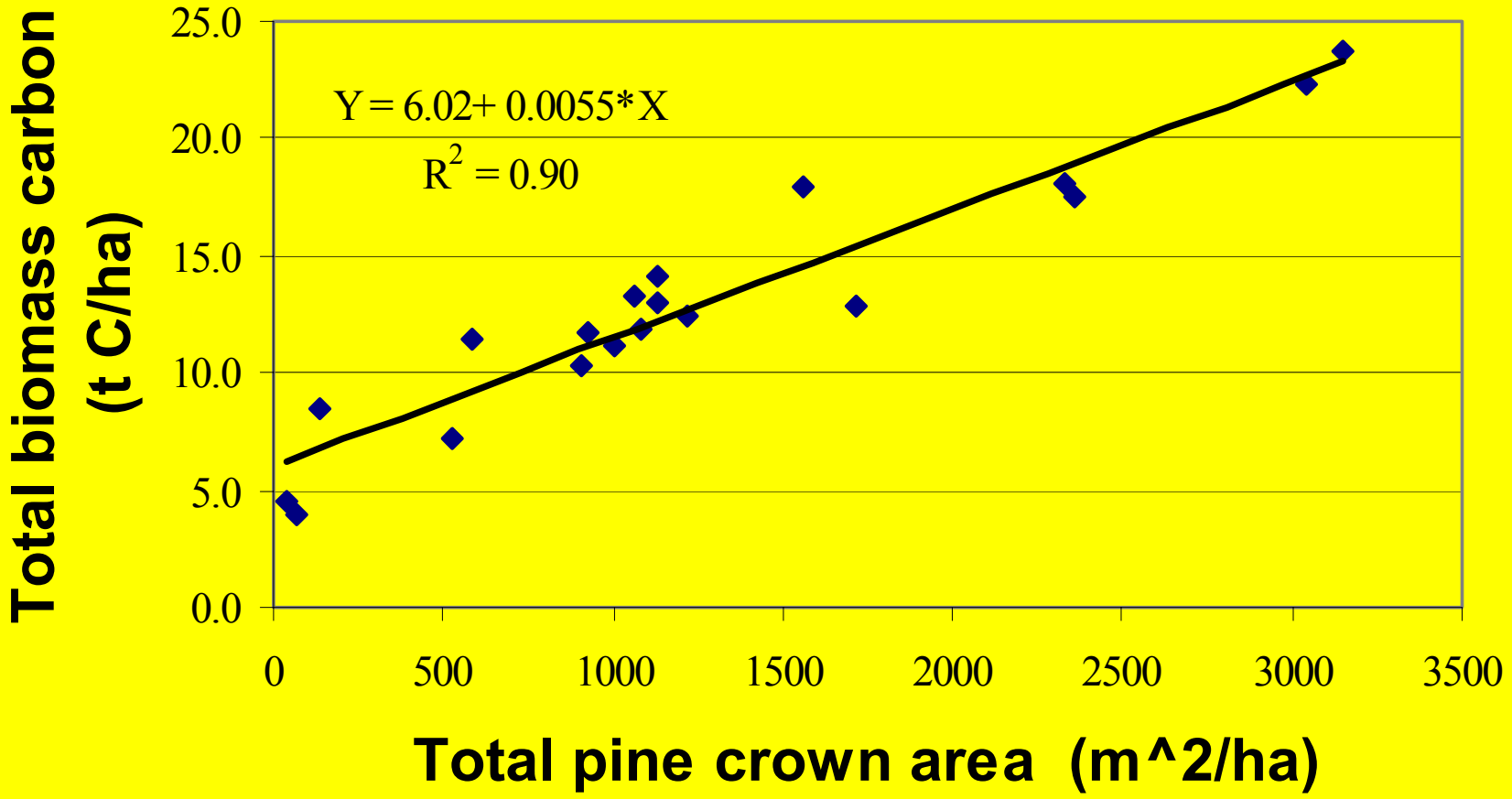
# Palmetto: trend in biomass with height



# Carbon stocks by vegetation type

| Plot number | Pine t C/ha | Shrub t C/ha | Palms t C/ha | Grass t C/ha | Total t C/ha |
|---|---|---|---|---|---|
| 1 | 3.4 | 0.4 | 0.2 | 2.6 | 7.1 |
| 2 | 7 | 3.0 | 0.1 | 1.7 | 11.8 |
| ..... | ..... | ..... | ..... | ..... | ..... |
| 19 | 5.3 | 3.3 | 0.1 | 1.7 | 10.3 |
| 20 | 6.1 | 3.4 | 0.0 | 1.6 | 11.1 |
| **Stats** | | | | | |
| **n=** | **19** | **19** | **19** | **19** | **19** |
| **Mean** | **7.7** | **3.3** | **0.4** | **1.5** | **12.9** |
| **SE** | **1.3** | **0.5** | **0.07** | **0.2** | **1.2** |
| **C.V. (%)** | **72.4** | **64.9** | **76.8** | **44.0** | **40.6** |
| **95% CI (% of mean)** | **25.7** | **22.4** | **29.6** | **15.7** | **16.1** |

# Total biomass carbon is a function of pine tree crown area



# Next steps:

- Reduce and quantify uncertainty of field measurements
  - Intensify field sampling of shrubs, palmettos, and grasses to improve relationships with digital imagery measures
  - Fill in some gaps in tree data, especially larger diameter trees
  - Estimate total error from application of various regressions

# Next steps:

- Improve digital imagery analysis:
  - Collect new imagery with new system giving higher resolution height data
  - Ground truth to confirm identification of oak and calabash trees
  - Reduce time to analyze imagery by using nested plots: 1 ha for all pine trees, 0.1 ha for small broadleaf trees; 0.01 ha for shrubs,palmettos, grasses
  - Refine model of total biomass carbon versus pine crown area

# Compare cost of imagery method with direct field method

- Imagery method:
  - Track person-hours to collect and analyze imagery and field data
  - Track person-hours to combine both sets of data for sufficient number of plots to reach precision of 10% of mean with 95% confidence
  - Estimate  total fixed and variable costs
  - Estimate likely cost for monitoring next event and for estimating change in carbon stocks
    - If model of biomass per ha versus pine crown area holds with new data, measure pine crown area only in subsequent monitoring periods
    - Thus will only need to collect and analyze imagery for pine trees, with considerable time savings

# Compare cost of imagery method with direct field method

- Direct field method:
  - Track-person hours to collect and analyze field data using standard field protocols for a given number of plots
  - Use the CV of the plot data to estimate number of plots needed to reach same level of precision as imagery method
  - Estimate total fixed and variable cost to measure all required number of plots at time one
  - Estimate total fixed and variable cost to monitor next event to estimate change in carbon stocks